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IRIG RECOMMENDED OPERATIONAL PROCEDURES FOR MULTIPLE DRONE MISSIONS

TELE-COMMUNICATIONS WORKING GROUP
INTER-RANGE INSTRUMENTATION GROUP
RANGE COMMANDERS COUNCIL

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FOREWORD

Although a "Digital Command Data System" would best meet the requirements for command control of multiple drones by providing a capability for transmitting a greater number of commands (control functions) to a greater number of drones (addressees) within a narrower bandpass, it must be realized that there are many limitations when trying to accomplish this with present hardware. Therefore, this document is in the form of a recommendation because it specifies operational procedures that provide for reliable and efficient utilization of command control equipment operating within the standards presented in IRIG Document 103-61, "IRIG System Standards for Radio Command Control 406-550 MHz Band."

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FIGURES

INTRODUCTION

This document recommends operational procedures for the efficient and reliable utilization of Radio Command Control equipment comprising the ground portion of the system and provides guidelines for determining equipment requirements for the airborne package in the drones. It is not intended to be restrictive to procedures presently in use.

Operational procedures, as referenced here, include the various equipment configurations required to provide an operational Radio Command Control System that will satisfy project or mission requirements.

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I. OPERATING PARAMETERS AND LIMITATIONS

A. OPERATING PARAMETERS: Shall conform to "General System Parameters and Criteria" as outlined in IRIG Document 103-61, "IRIG System Standards for Radio Command Control 406-550 MHz Band."

B. LIMITATIONS:

1. A serious limitation requiring consideration in the control of multiple drones when utilizing one carrier frequency is the total number of simultaneous command tones that can be effectively transmitted and received. Equipment manufacturers of the transmitting or ground portion of the Command Control System indicate that there are no limitations in transmitting all twenty IRIG command tones simultaneously; however, the majority of equipment manufacturers of airborne command receivers specify that the maximum number of command tones that can be received simultaneously is six.

2. Other limitations requiring consideration would also be in the airborne command receiver, e.g., modulation deviation requirements and overall receiver bandpass.

3. The ground transmitting equipment is flexible in this respect since the modulation deviation of the command tone or tones can be adjusted to satisfy requirements and the equipment can be operated with or without compression of the command tone or tones.

4. The total number of commands required for each drone would also be a limiting factor in the number of drones that could be reliably operated in any given mission.

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II. OPERATIONAL AND EQUIPMENT CONFIGURATIONS

A. PRESENT OPERATIONAL METHODS

Figure 1 represents a dual drone operational method, presently in use, requiring two transmitters operating on two different frequencies. The airborne command receivers are identical except for operating frequency. This type of operation could be expanded to three or more drones requiring three or more transmitters and operating frequencies.

B. RECOMMENDED OPERATIONAL METHODS

1. Figure 2 represents a dual drone operation using one transmitter and one operating frequency. The major change in the airborne command receivers is that the tone filters in each drone respond to a different set of command tone frequencies for like command functions since both receivers are operated in the same frequency. This type of operation could also be expanded to three or more drones; however, the number of drones to be operated is limited by the number of command functions required for each drone. For example, four drones could be operated in this manner providing that no more than five command control tones were required for the control of each drone, or three drones could be operated with as many as eight command control tones, which would provide each drone with six individual control functions plus two control functions common to each drone.

2. Advantages to be gained by the operational procedures shown in Figure 2 are:

a. Efficient utilization of premium frequency spectrum.

b. Economy by efficient utilization of equipment.

c. Maximum system reliability by utilizing one of the transmitters as backup in a standby operation.

d. Compatibility in operating procedures for the transmitting or ground portion of the system.

3. Disadvantages that are inherent in the operating procedures shown in Figure 2 are:

a. The number of drones to be operated would be limited by the number of command functions required for each drone.

b. Total number of simultaneous command functions to be transmitted to each drone is limited by the receiver manufacturer's specifications. For instance, assuming that the receiver manufacturer specifies that the total number of command tones that can be received simultaneously is limited to six, and that two drones are being operated requiring simultaneous commands, then this would allow three simultaneous command functions to be transmitted to each drone (a total of six) because the three command functions, not being utilized by one of the drones, are utilizing receiver bandpass spectrum in that drone.

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III. LOGIC CONFIGURATIONS AND LIMITATIONS

A. LOGIC CONFIGURATIONS

1. Figure 3 illustrates relay outputs for a typical airborne command control receiver. Although only seven relay outputs are shown, most airborne command control receivers are (or can be) equipped with twenty. These relays are operated upon receipt of a transmitted command control tone which must be accepted by the tone filter preceding the relay activating circuitry.

2. Figure 4 illustrates one method of increasing the number of control functions within the drone by using two tone combinations. A maximum of eleven control functions can be obtained within the drone by this method, using a total of seven command control tones. External relays can be used in series with any of the control tones for control of functions where an isolated circuit is required. Following the same theory illustrated in Figure 4, a total of five command control tones would provide a maximum of seven control functions in the drone, whereas ten command control tones would provide for a maximum of 17 control functions within the drone.

3. Figure 5 illustrates another method for increasing the number of control functions with a given number of command control tones. A maximum of 21 control functions can be provided when using a total of seven command control tones in two tone combinations. This is accomplished by using diode logic in conjunction with transistor switches (not shown) for the control of functions in the drone. Relays may be substituted for current limiting resistors for control functions where transistor switching is not applicable, or where an isolated circuit is required. The chart below denotes the maximum number of control functions that can be obtained using a given total of command control tones.

Number of Command Tones	Number of Control Functions
5	10
6	15
7	21
8	28
9	36
10	45

4. Figure 6 illustrates a binary approach to increasing the number of control functions for a given number of command control tones. A maximum of 15 control functions can be provided when using a total of four command control tones in any one of the 15 possible combinations. This is accomplished by using two 8PDT relays, one 4PDT relay, and one DPDT relay in the configuration shown in Figure 6. Four DPDT relays, with the coils connected in parallel, could be used for an 8PDT relay; and two DPDT relays, with the coils connected in parallel, could be used for the 4PDT relay. A total of 11 DPDT relays could be used if the 8 PDT and 4PDT relays were not readily available. Following the same theory illustrated in Figure 6, a total of five command control tones would provide a maximum of 31 control functions. In any case, the number of control functions may be stated 2^n-1, where n is the number of command control tones being used.

B. LIMITATIONS

1. Operational limitations using the two tone logic represented in Figure 4 are restricted to control functions in the second group whenever a control function in the first group is being transmitted; consequently, the first group would be any control function requiring command control tone one, which in this case would be control functions 1, 2, 4, 6, 8, and 10; and the second group would be any control function requiring command control tone two, which in this case would be control functions 3, 5, 7, 9, and 11.

a. Control functions will respond individually or simultaneously to command control tones sent solely for control functions in group one, or solely for control functions in group two. However, control functions in group two will automatically be preempted whenever control functions in group one are responding to command control tones.

b. Careful selection of control functions for proper grouping is required in this application so that control functions requiring simultaneous operation can be included within one of the groups.

2. The two tone logic illustrated in Figure 5 provides for a greater number of control functions; however, the operation is limited to individual control functions and is not easily adaptable to an operation requiring simultaneous control functions within a drone. For example, an operation requiring two simultaneous control functions would not be feasible, because two command control tones are required to provide one control function, and three command control tones would provide three simultaneous control functions instead of two.

3. The binary output command logic illustrated in Figure 6 provides for a maximum number of control functions for any given number of command control tones. This type of operation is limited to singular control functions for any given time period, and does not lend itself to an operation requiring simultaneous control functions.

However, diode isolation logic following a singular control function can be used to provide simultaneous functions when required The greatest limitation imposed by this approach is the response time Figure 6 shows that control function three requires that all K1 and K2 relays be energized Since the relays are mechanical devices it is not only possible, but quite probable that the operating time between relays will vary This variance in relay operating time will cause control function one or control function two to be activated for a small fraction of time (a few milliseconds) before control function three is solidly activated This same process is likely to be repeated when the relays are deenergized Other factors having a decided effect in this area would be velocity versus bandwidth characteristics of the command tone frequencies used, plus any time delays between the initiation of simultaneous command control tones for a given function at the ground encoder However, time delays at the encoder can be minimized by using control function switches followed by diode isolation logic for the simultaneous initiation of the command control tones required for the given function

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IV. CONCLUSIONS

The contents of this document do not fully explore all of the approaches or the logic that could be applied for efficient and reliable utilization of equipment, but they do provide basic information for developing an operational procedure that will satisfy the various requirements encountered in multiple drone operations.

The purpose of this document, then, is to promote operational procedures that represent the best compromises even though the approaches shown in this document are not utilized.

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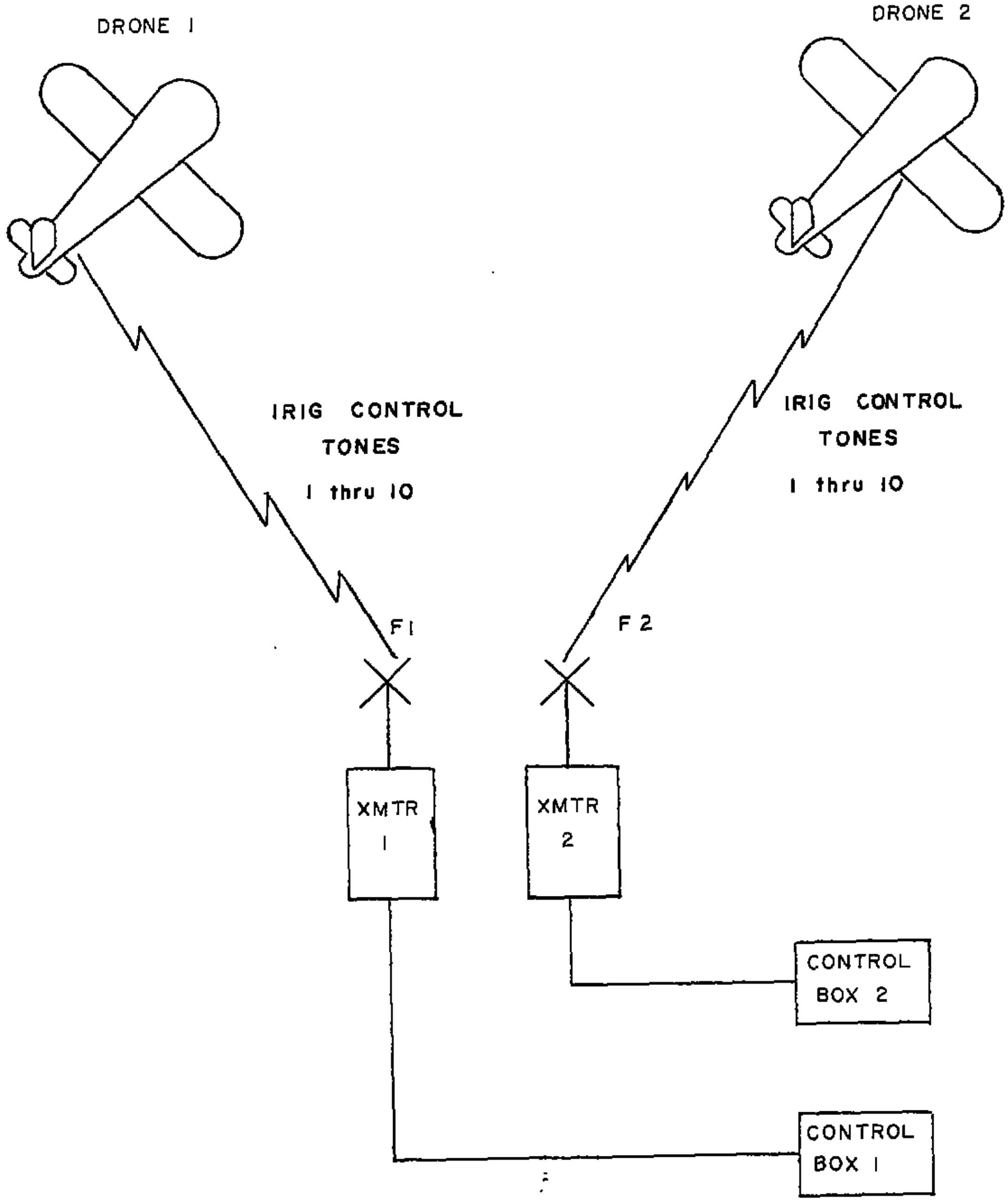
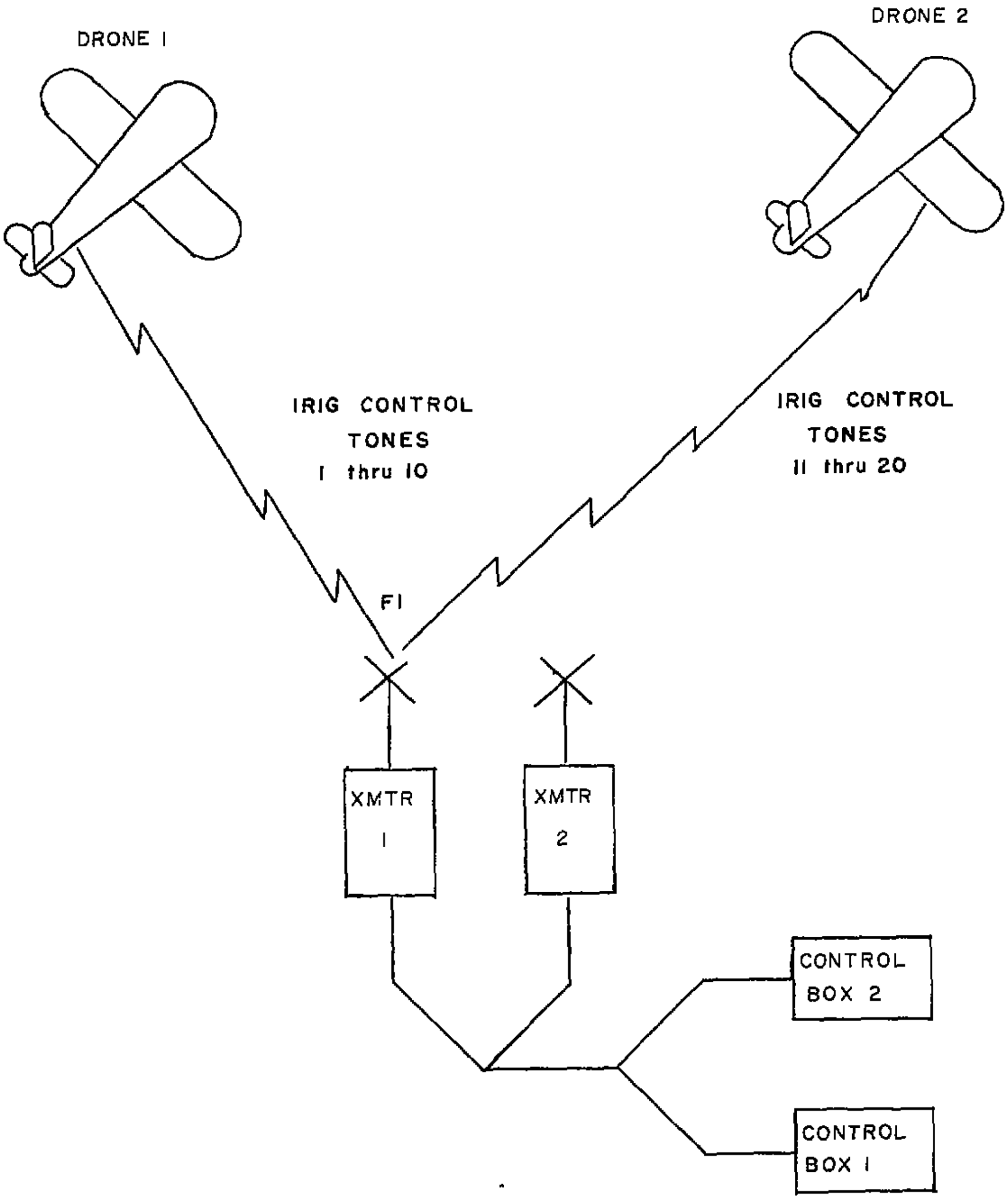


F1 - OPERATING FREQUENCY DRONE 1
F2 - OPERATING FREQUENCY DRONE 2
XMTR 1 - NORMAL TRANSMITTER
XMTR 2 - STANDBY TRANSMITTER
CONTROL BOX 1 - CONTROL DRONE 1
CONTROL BOX 2 - CONTROL DRONE 2

PRESENT OPERATIONAL CONFIGURATION
FIGURE 1



F1 - OPERATING FREQUENCY DRONE 1 AND 2
XMTR 1 - NORMAL TRANSMITTER
XMTR 2 - STANDBY TRANSMITTER
CONTROL BOX 1 - CONTROL DRONE 1
CONTROL BOX 2 - CONTROL DRONE 2

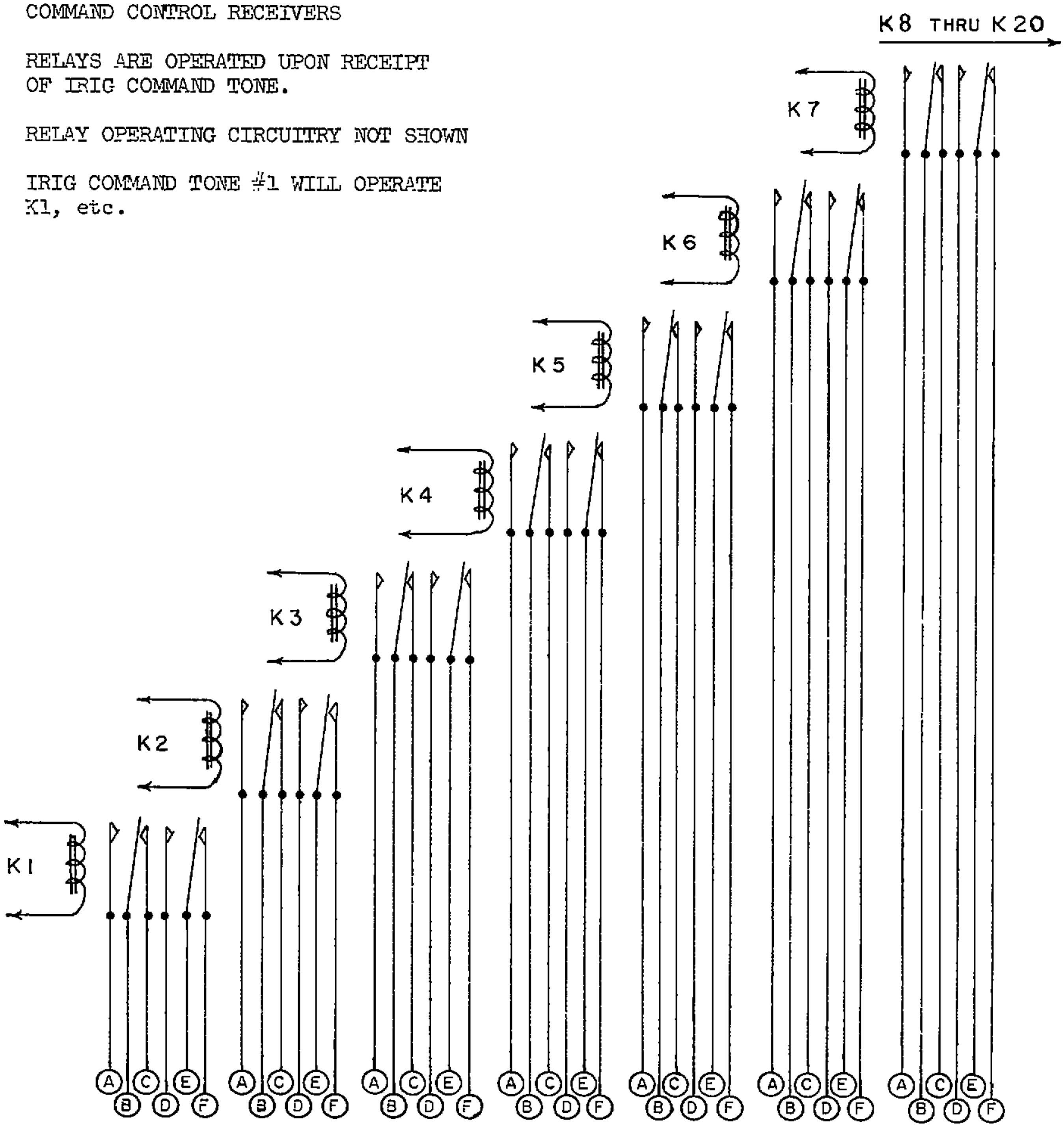
RECOMMENDED OPERATIONAL CONFIGURATION
FIGURE 2

TYPICAL RELAY OUTPUTS IN TONE
DECODER PORTION OF AIRBORNE
COMMAND CONTROL RECEIVERS

RELAYS ARE OPERATED UPON RECEIPT
OF IRIG COMMAND TONE.

RELAY OPERATING CIRCUITRY NOT SHOWN

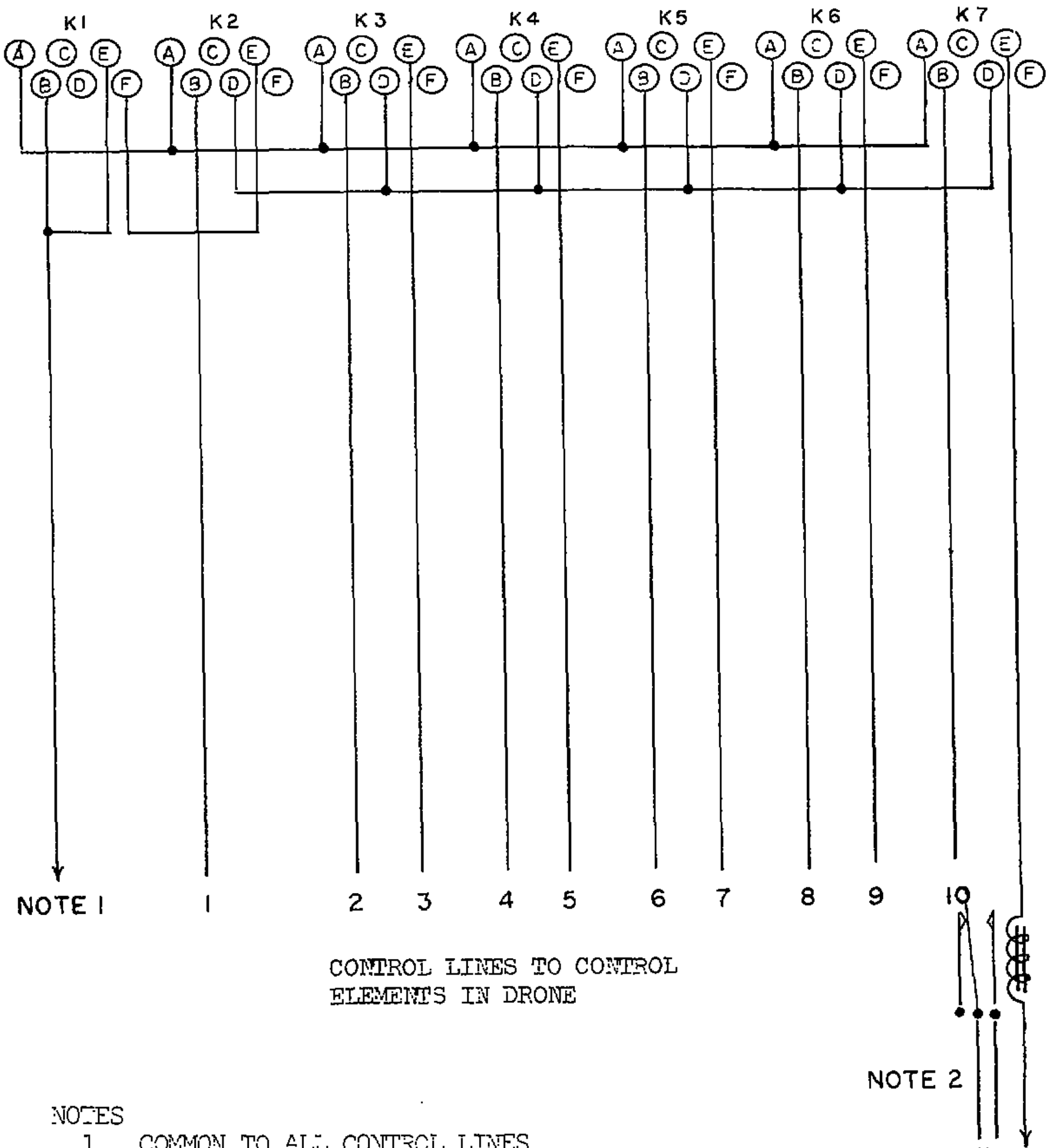
IRIG COMMAND TONE #1 WILL OPERATE
K1, etc.



OUTPUT TO CONTROL ELEMENTS IN DRONE

FIGURE 3

WIRING EXTERNAL TO COMMAND CONTROL RECEIVERS
FOR INCREASING CONTROL FUNCTIONS TO CONTROL
ELEMENTS IN DRONE

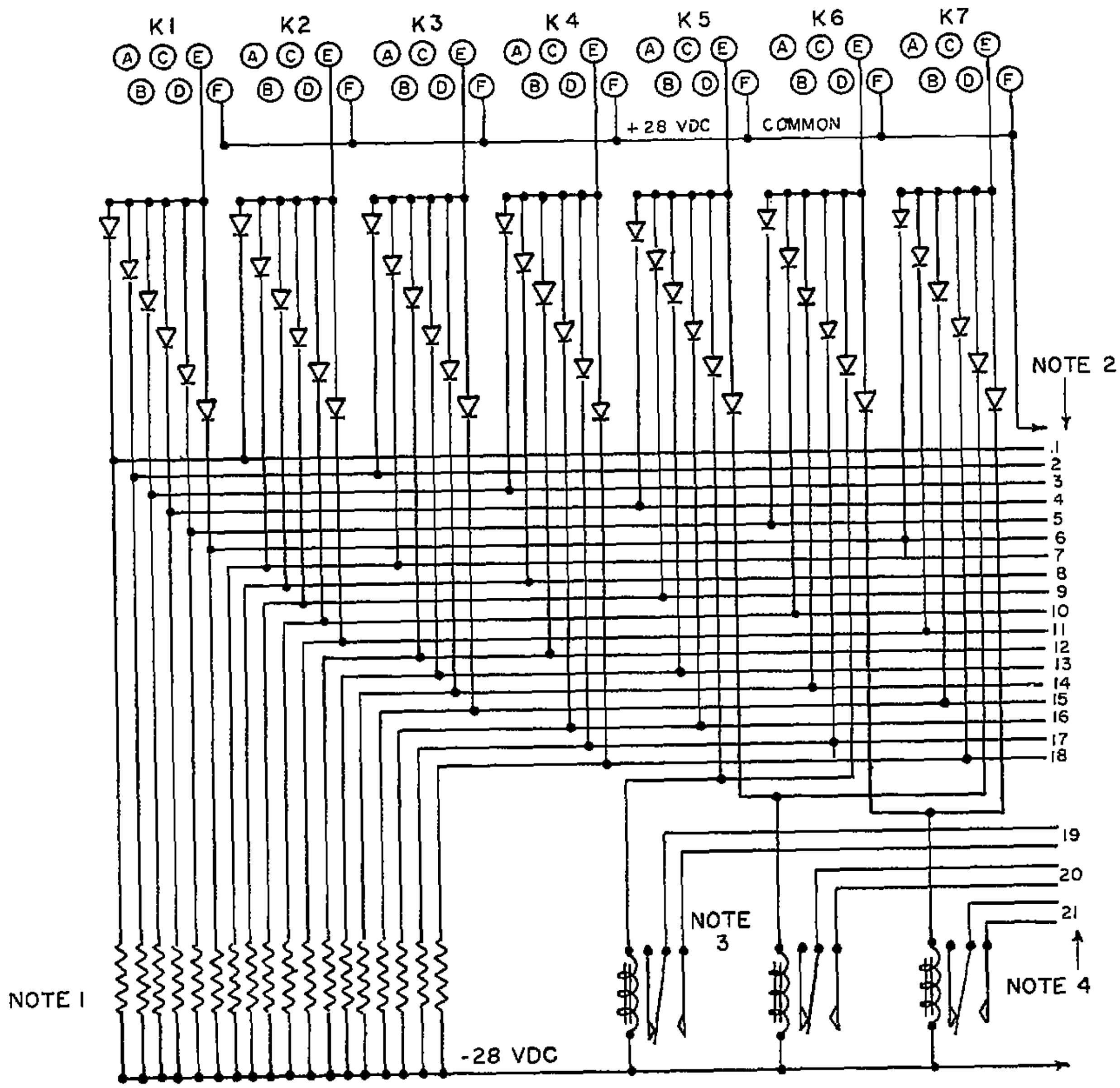


NOTES
1. COMMON TO ALL CONTROL LINES
2. RELAYS MAY BE OUT BOARDED FOR CONTROL FUNCTIONS WHERE AN ISOLATED COMMON IS REQUIRED.

TWO TONE LOGIC

FIGURE 4

SEMICONDUCTOR LOGIC AND SWITCHING



NOTES

1. CURRENT LIMITING RESISTORS
2. CONTROL LINES TO TRANSISTOR SWITCHES FOR INITIATING COMMAND FUNCTIONS.
3. RELAYS SUBSTITUTED FOR CURRENT LIMITING RESISTORS FOR CONTROL FUNCTIONS WHERE TRANSISTOR SWITCHING IS NOT APPLICABLE.
4. RELAY OUTPUTS FOR INITIATING TRANSMITTED COMMAND FUNCTIONS.

FIGURE 5

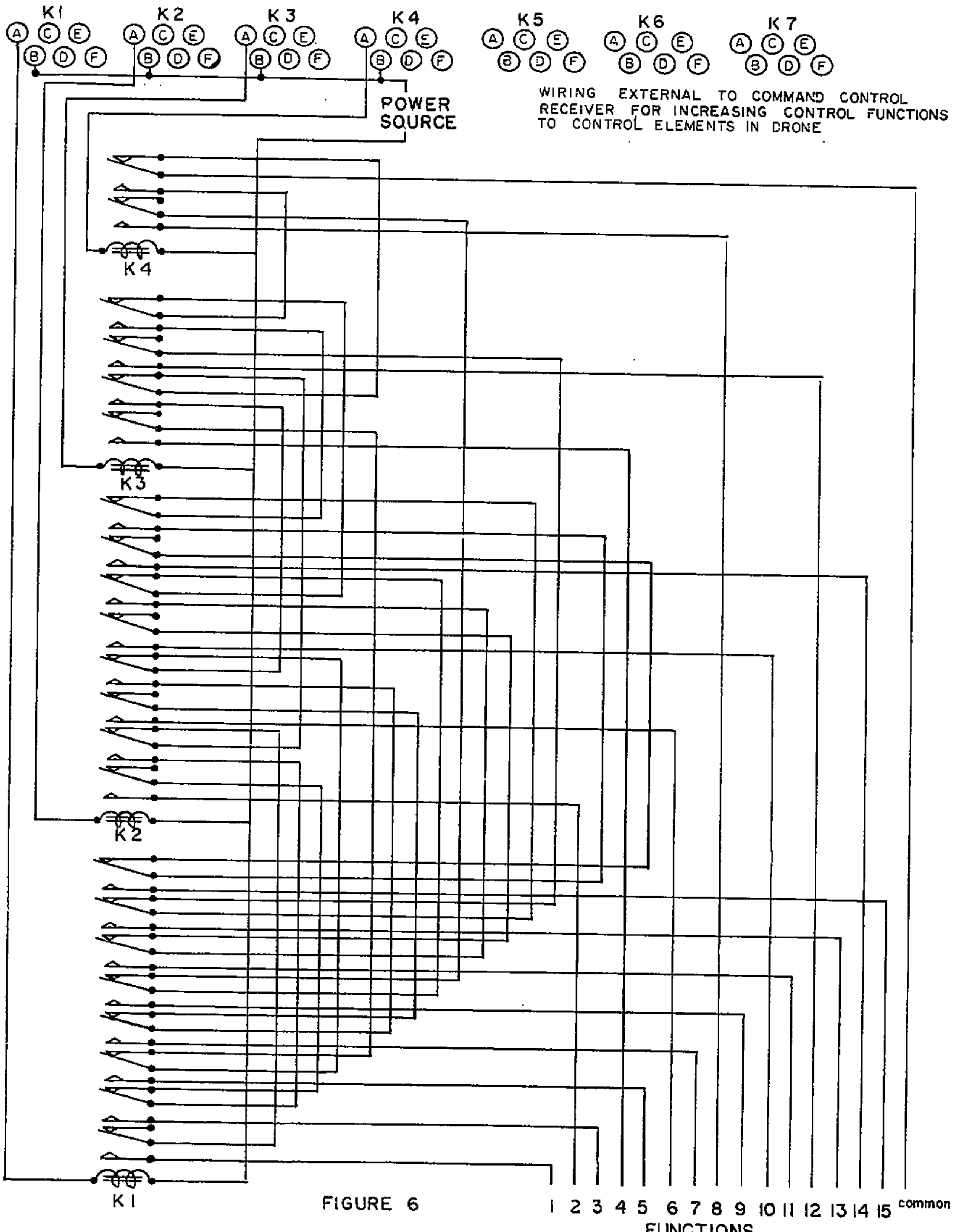


FIGURE 6

AFLC/HAFB, Ogden